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PREDICTION OF ACADEMIC PERFORMACE
OF THE U.S. NAVY OFFICER STUDENTS IN THE
OPERATIONS RESEARCH/SYSTEMS ANALYSIS
CURRICULUM AT THE NAVAL POSTGRADUATE SCHOOL

Heru Soetrisno

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THESIS

PREDICTION OF ACADEMIC PERFORMANCE
OF THE U.S. NAVY OFFICER STUDENTS IN THE
OPERATIONS RESEARCH/SYSTEMS ANALYSIS
CURRICULUM AT THE NAVAL POSTGRADUATE SCHOOL

by

Heru Soetrisno

March 1975

Thesis Advisor:

R.S. Elster

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Prediction of Academic Performance
of the U.S. Navy Officer Students in the
Operations Research/Systems Analysis Curriculum
at the Naval Postgraduate School

by

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Submitted in partial fulfillment of the
requirements for the degree of

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Several prediction equations were derived using a development sample and then cross-validated using a hold-out sample; the results were statistically significant. Four of the prediction equations derived were selected to be further analyzed to obtain regression coefficients using the Jackknife procedure. No significant differences were found between the results obtained using the Stepwise Regression procedure and the Jackknife procedure.

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I. INTRODUCTION

A. PURPOSE OF STUDY

The purpose of this study was to assess the characteristics of the U.S. Navy officer students registered in the Operations Research/System Analysis curriculum at the U.S. Naval Postgraduate School by means of a Biographical Questionnaire, the Graduate Record Examination and the Strong Vocational Interest Blank and determine if these measures offered a means of improving the selection of U.S. Naval officers for enrollment in the Operations Research/Systems Analysis curriculum.

This study was a portion of the NPS Student Selection Project sponsored by the Navy Personnel Research and Development Center, concerning the prediction of officer/student academic performance and satisfaction in graduate curricula at the U.S. Naval Postgraduate School.

Only academic performance was investigated in the study since two previous studies, conducted by Cook [1] and Sofge [2], found that none of the predictors of satisfaction cross-validated at a statistically significant level.

B. U.S. POSTGRADUATE SELECTION PROCESS

The Postgraduate Education Selection Board in the Navy's Bureau of Personnel (BuPers) is in charge of selecting Navy Officers best suited for courses in the postgraduate program

based on the individual's preference for postgraduate curricula, professional performance, prior academic performance, promotion potential and the needs of the service [3].

The needs of the service are determined by the Chief of Naval Personnel and sent to the Board annually.

An officer's prior academic performance is translated into an Educational Potential Code (EPC) based upon an evaluation of previous grades. The EPC is supposed to be weighted 40% by the Board.

An officer's professional performance is supposed to be weighted 60%. The Officer's Fitness Reports are used as the primary indicator of professional performance [3].

Upon completion of the selection process, the Board sends a list of principle and alternate selectees to the Officer Detailing Section of BuPers. The Detailers then decide which of these selected officers are available for education. A more detailed description of this selection procedure is provided by R.S. Elster [3].

C. DEFINITION OF KEY TERMS

1. The Quality Point Rating (QPR), is a student's weighted grade score computed from standards established by the Naval Postgraduate School [4] as follows:

<u>Grade</u>	<u>Point Value</u>
A	4.0
A-	3.7
B+	3.3
B	3.0
B-	2.7
C+	2.3
C	2.0
C-	1.7
D+	1.3
D	1.0
X	0.0

Multiplying the credit-hours value of a course by the point value received provides the total quality points for that course. Adding the quality points for all courses and dividing by the total number of credit hours results in a figure defined as a Quality Point Rating (QPR). For example, if a student received four hours of A, four hours of A- and four hours of B, his QPR would be:

$$\frac{4 \times 4 + 4 \times 3.7 + 4 \times 3}{4 + 4 + 4} = 3.57$$

2. The Graduate Record Examination is a widely accepted paper and pencil aptitude test designed to predict academic potential at the graduate level. The GRE is a secure test which is administered under controlled conditions and yields two scores: verbal ability (GREV) and quantitative ability (GREQ) [5]. It is prepared and published by the Education Testing Service of Princeton, New Jersey.

3. The Strong Vocational Interest Blank (SVIB), is a test to assess individual interests as related to interests

of incumbants in various occupations [6]. The SVIB contains 399 items, listing school subjects, hobbies and activities to which the individual's response is either like, dislike, or indifferent.

4. Biographical Questionnaire. This questionnaire was designed to obtain historical/biographical facts from officers/students as well as attitudes toward postgraduate education and its place in today's U.S. Navy. The questionnaire contained 61 questions which required "yes" or "no" responses, and was developed by R.A. Weitzman with the assistance of J.L. Cook [1].

5. Correlation Coefficient. The Simple Correlation Coefficient is a measure of linear association between two random variables Y and X [7]. The Multiple Correlation Coefficient is a measure of linear association between a random variable Y and a set of random variables

$$\underline{X} = (X_1, X_2, \dots, X_p) \text{ [7].}$$

The range of possible values of the Correlation Coefficient is from -1.00 to +1.00. A correlation of 0.00 indicates that knowledge of the value of \underline{X} gives no information about Y .

6. The Reliability Coefficient, is a measure of consistency or stability of test results. It is often obtained by inter-correlating the test with the results if the test is retaken in the same or alternate form, or it is obtained by splitting the test into two parts and intercorrelating the two sets of scores [8].

7. Validity is the effectiveness of the test in representing, describing or predicting the attribute that the test purports to measure [8].

8. Cross-Validation: Testing out of a set of items or system of test weights derived from one sample, to see to what extent the procedure or equation retains its validity with a new and independent sample. Cross-Validation is especially important when items or test weights have been chosen from a large number of possible alternatives, and when the original sample was small [8].

D. ASSUMPTIONS

It was assumed that academic performance, represented by Quality Point Rating is related to some predictors, such as biographical items, prior academic performance, SVIB scores or GRE scores.

E. LIMITATION

This study was limited to male, U.S. Navy Officer Students who were enrolled in the Operations Research/Systems Analysis curriculum in Spring 1974.

II. DESCRIPTION OF INSTRUMENTS

A. GRADUATE RECORD EXAMINATION (GRE)

This test is used in efforts to determine student's aptitudes for postgraduate study. Included in the test are verbal reasoning questions, reading comprehensive questions and various kinds of mathematical problems involving arithmetic reasoning, algebra and the interpretation of graphs, diagrams and descriptive data [5]. Established reliabilities for the test are: [9]

<u>Test</u>	<u>Reliability Coefficient</u>
Verbal	0.90
Quantitative	0.89

The GRE has increased in utilization as a selection tool. There were 22,000 candidates tested in 1958 and the number has increased since then. Over 300,000 candidates were tested in 1973 [10].

Previous studies of the validity of the GRE in predicting academic performance at the U.S. Naval Postgraduate School were conducted by Kauder and Ebert in 1963, Dreese and Russel in 1964, and Cook in 1974. The first two studies obtained over 0.45 validation correlations while the later one obtained a correlation of 0.37 with a relatively small sample size ($N = 30$).

B. STRONG VOCATIONAL INTEREST BLANK (SVIB)

The primary use of the Strong Vocational Interest Blank is for counseling high school and college students about their career choices. However this test can also be used for personnel selection. When used by a professionally trained person, the SVIB can provide useful information for evaluating an applicant [6].

The basic SVIB documents are a test booklet containing the items, an answer sheet where an individual records his responses, and the profile forms that are used to report the results.

The SVIB has two types of scales, occupational scales and non-occupational scales. People in different occupations have different interests. The SVIB is a device to identify such differences among those occupations. The SVIB scores are used to counsel individuals regarding occupations in which they would be satisfied. The SVIB accomplishes this by providing an index of the similarity between a person's interests and those of men (or women) in each of a wide range of occupations. Basically, the technique used in SVIB is to present the individual with a long list of activities and ask him to indicate which he likes and dislikes. The answers are analyzed by comparing his responses to those of men (or women) already established in a wide range of activities. If his choices coincide with say, engineers, then he received a high score on the engineers scale. The mean score for a particular occupation has been set at 50 with a standard deviation of 10.

The Academic Achievement scale (AACH) as one of the non-occupational scales is an attempt to identify the pattern of interests associated with good scholarship. The scale included items that differentiate between good and poor students. It has been shown to be moderately effective in predicting grades [6].

C. BIOGRAPHICAL QUESTIONNAIRE

The questionnaire was developed to obtain the following information:

1. Source of commission and/or prior enlisted service.
2. Rank.
3. Undergraduate institution attended, degree received, undergraduate major and grade point average.
4. Warfare specialty.
5. Race.
6. Height and weight.
7. Religion.
8. Marital status and/or sex dependents.
9. Birth-order of subject.
10. Educational level of father.
11. Military career of father.
12. High school background information.
13. Personal habits.
14. Participation in Boy Scout and rank attained.
15. Designation by Postgraduate Selection Board.

16. Satisfaction with the Naval Postgraduate School and/or curriculum.
17. Possible future use of skills obtained at the Naval Postgraduate School.
18. Mathematics background.
19. Motivation for coming to the Naval Postgraduate School.

The questionnaire utilized a booklet with 61 questions, each of which required "yes" or "no" responses. The responses were recorded on a separate sheet. The answer sheet also contained an administrative section which required information such as: Social Security number (for identification), current curriculum, number of quarters completed in current curriculum, and QPR.

III. METHODS, TECHNIQUES AND PROCEDURES

A. GENERAL

Seventy-two U.S. Navy officer students in the Operations Research/Systems Analysis curriculum at NPS who were at various stages in their curriculum when the data were collected (quarter 3, Academic Year 73-74) constituted the population of this study. A random sample of 50 students was randomly selected from the population for the development of predictors of academic performance. The remaining sample constituted the cross-validation sample.

B. LINEAR REGRESSION ANALYSIS

The purposes of Linear Regression are to select the set of explanatory variables which should be included in a model, and then to estimate the regression coefficients which describe the quantitative weights of these variables.

The model to be used, in matrix notation, has the form:

$$\underline{Y} = \underline{XB} + \underline{e}$$

where

$$\underline{Y} = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} ; \quad \underline{B} = \begin{bmatrix} B_0 \\ B_1 \\ \vdots \\ B_p \end{bmatrix} ; \quad \underline{e} = \begin{bmatrix} e_1 \\ e_2 \\ \vdots \\ e_n \end{bmatrix}$$

$$X = \begin{bmatrix} 1 & X_{11} & X_{12} & \cdot & \cdot & \cdot & X_{1p} \\ 1 & X_{21} & X_{22} & \cdot & \cdot & \cdot & X_{2p} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 1 & X_{n1} & X_{n2} & \cdot & \cdot & \cdot & X_{np} \end{bmatrix}$$

It was assumed that

1. $E(\underline{e}) = \underline{0}$, hence $E(\underline{Y}) = X\underline{B}$
2. The components of \underline{e} are identically and independently distributed, hence the variance covariance matrix for the vector variables \underline{e} is

$$E(\underline{e} \underline{e}') = C_{n \times n}^2 I$$

The Gauss-Markov theorem states that "the least squares estimators have minimum sampling variance in the class of all unbiased estimators which are linear functions of \underline{Y} ." To obtain the least square estimators, one minimizes $\underline{e}'\underline{e}$, where $\underline{e} = \underline{Y} - X\underline{B}$, with respect to \underline{B} . This yields:

$$\hat{\underline{B}} = (X'X)^{-1}X'\underline{Y},$$

where $\hat{\underline{B}}$ is the estimator of \underline{B} , provided that $(X'X)$ is non-singular.

To test the hypothesis of $\underline{B} = \underline{B}^*$ against the alternative hypothesis $\underline{B} \neq \underline{B}^*$, one uses Analysis of Variance criteria.

All Analysis of Variance tests are based on what is known as the Likelihood Ratio test.

In the case of the model

$$\underline{Y} = X\underline{B} + \underline{e} ,$$

we need another assumption, that is \underline{e} is distributed as multivariate normal with mean $\underline{0}$ and variance $C^2 I$, hence

$$\underline{Y} \sim N(X\underline{B}, C^2 I)$$

and the likelihood function has the form:

$$L(\underline{Y}, \underline{B}, C^2) = \frac{1}{(2\pi)^{n/2}} e^{-\frac{1}{2C^2}(\underline{Y} - X\underline{B})'(\underline{Y} - X\underline{B})} .$$

Consider maximizing the likelihood function with respect to \underline{B} and C^2 under two situations. The first case is when we allow \underline{B} and C^2 to take on any value they wish in the range $(-\infty \leq \underline{B} \leq \infty; C^2 \geq 0)$. Denote this range Ω . This is the unrestricted case and the maximum value of the likelihood function will be denoted $L(\hat{\Omega})$. The second case is when the restriction on the parameters $\underline{B} = \underline{B}^*$; $C^2 \geq 0$. This range is denoted by W and the maximum value of the likelihood function under the restriction of the hypothesis is denoted $L(\hat{W})$. We would reject the hypothesis $\underline{B} = \underline{B}^*$ in favor of alternative hypotheses $\underline{B} = \underline{B}^*$ if in fact:

$$L = \frac{L(\hat{W})}{L(\hat{\Omega})} < k$$

for some constant $k < 1$ where k is chosen such that the probability of rejecting the hypothesis when it is true is equal to α (usually $\alpha = 5$ or 10%). That is, select k such that

$$\alpha = \int_{-\infty}^{\infty} g(L|H_0 \text{ is true}) dL$$

where $g(L|H_0 \text{ true})$ is the distribution of the likelihood ratio when H_0 is true.

Maximizing $L(\underline{Y}, \underline{B}, C^2)$ with respect to \underline{B} and C^2 under Ω and W gives the likelihood ratio

$$L = \left[\frac{(\underline{Y} - \hat{X}\hat{B})' (\underline{Y} - \hat{X}\hat{B})}{(\underline{Y} - X\hat{B}^*)' (\underline{Y} - X\hat{B}^*)} \right]^{n/2}$$

with $\hat{B} = (X'X)^{-1}X'\underline{Y}$.

The numerator of the likelihood ratio (ignoring the power $n/2$) may be expressed as

$$(\underline{Y} - X\hat{B}^*) (I - XS^{-1}X') (\underline{Y} - X\hat{B}^*) ,$$

where

$$S^{-1} = (X'X)^{-1} .$$

The denominator of the likelihood ratio may be expressed as:

$$(\underline{Y} - \underline{XB}^*)' (I - \underline{XS}^{-1}\underline{X}') (\underline{Y} - \underline{XB}^*) + (\underline{Y} - \underline{XB}^*)' (\underline{XS}^{-1}\underline{X}) (\underline{Y} - \underline{XB}^*)$$

Hence, L may be written with $\underline{Z} = (\underline{Y} - \underline{XB}^*)$ as:

$$L = \left[\frac{\underline{Z}' \underline{A}_1 \underline{Z}}{\underline{Z}' \underline{A}_1 \underline{Z} + \underline{Z}' \underline{A}_2 \underline{Z}} \right]^{n/2}$$

where

$$\underline{A}_1 = (I - \underline{XS}^{-1}\underline{X}')$$

$$\underline{A}_2 = (\underline{XS}^{-1}\underline{X}')$$

and it also can be proven that \underline{A}_1 and \underline{A}_2 are idempotent matrices ($\underline{A}_1^2 = \underline{A}_1$, $\underline{A}_2^2 = \underline{A}_2$) with rank $(n - p)$ and p respectively.

Since $\underline{Y} \sim N(\underline{XB}, C^2 I)$ then $\underline{Z} \sim N(\underline{XB} - \underline{XB}^*, C^2 I)$ and also since \underline{A}_1 and \underline{A}_2 are idempotent and $\underline{A}_1 \underline{A}_2 = 0$ then

$$\frac{\underline{Z}' \underline{A}_1 \underline{Z}}{C^2} \quad \text{and} \quad \frac{\underline{Z}' \underline{A}_2 \underline{Z}}{C^2}$$

are independent Chi-Squares:

$$\frac{\underline{Z}' \underline{A}_1 \underline{Z}}{C^2} \sim \chi^2(n - p)$$

and

$$\frac{Z'A_2Z}{C^2} \sim \chi^2(p;\lambda) ,$$

where λ is the non centrality parameter and its value is equal to

$$\lambda = \frac{1}{2C} (\underline{B} - \underline{B}^*)' X' X (\underline{B} - \underline{B}^*) .$$

Note, that although the ratio

$$\frac{Z'A_1Z/C^2}{Z'A_1Z/C^2 + Z'A_2Z/C^2}$$

is not the ratio of two independent Chi-Squares and hence not distributed F, the statistic

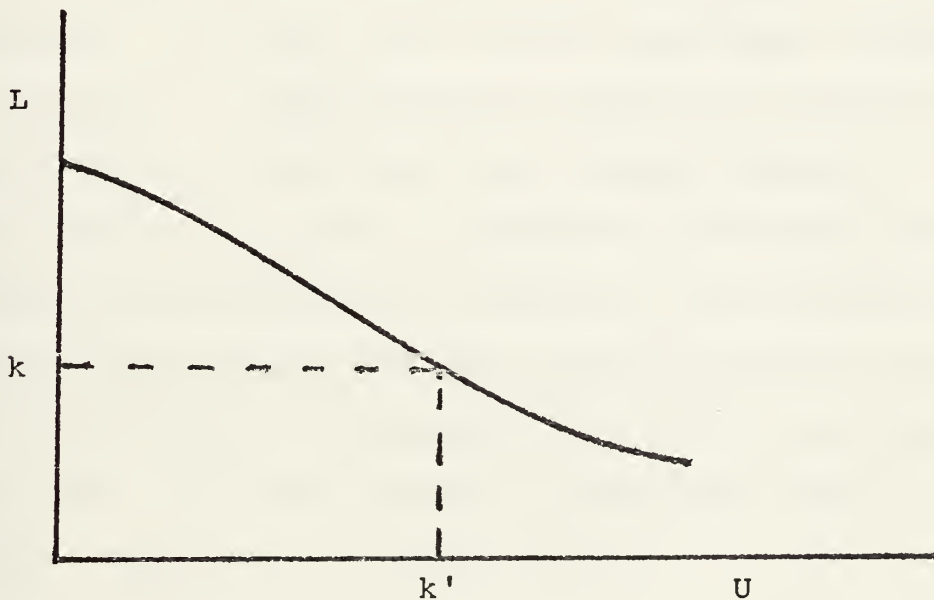
$$U = \frac{(Z'A_2Z/C^2)/p}{(Z'A_1Z/C^2)/(n-p)}$$

is the ratio of two independent Chi-Squares divided by their respective degrees of freedom. Moreover, the denominator is distributed as central Chi-Square and the numerator is distributed as non central Chi-Square and, hence, the ratio is distributed as $F(p, n-p, \lambda)$. If the hypothesis $\underline{B} = \underline{B}^*$ is true, the noncentrality parameter $\lambda = \frac{1}{2}(\underline{B} - \underline{B}^*)' \frac{X'X}{C^2} (\underline{B} - \underline{B}^*)$ is zero and the U statistic is distributed as central $F(p, n-p)$.

To show that the F test and the likelihood ratio test are equivalent, we note that

$$L = \left[\frac{Z'A_1Z}{Z'A_1Z + Z'A_2Z} \right]^{n/2} = \left[\frac{1}{1 + \frac{p}{n-p} U} \right]^{n/2} .$$

U and L are monotonically related in a manner given in the graph below.



The likelihood ratio test is said to reject H_0 when $L < k$ where k is chosen to give a significant test of level α . But this is identical to rejecting H_0 when $U > k'$ where k' is chosen to give a significant test of the same level and since we know the distribution of U when H_0 is true we can select k' from the appropriate F table [11].

In many situations, there is not sufficient information about the order of importance of the independent variables

X_1, \dots, X_p in predicting the dependent variable Y . Testing $H_0: B_i = 0$ for each variable X_i does not reveal this ordering. For instance, rejecting the H_0 that $B_1 = 0$ while accepting the remaining $B_i = 0$ could have led to the false conclusion that X_1 was the only variable of importance in predicting Y [7].

One solution is the Stepwise Regression procedure which selects a best subset of predictors according to the following procedures: The first step selects the single variable which best predicts Y . The second step finds the variable which best predicts Y , given the first variable entered. In the steps that follow, either a variable is entered which best improves the prediction of Y given all the variables entered from the previous step, or a variable is removed from the set of predictors if its predictive ability falls below a given level [7]. The process is terminated when no further variable improves the prediction of Y .

C. JACKKNIFING

Least square estimations provide unbiased estimators as long as the specified model is correct. But, at the early stages of regression the model is not complete. Hence the estimators may be biased. Generally this bias diminishes as the sample size increases. One way to eliminate this is to use the Jackknife procedure.

The rationale behind the Jackknife is as follows [12]: Let $\hat{\theta}$, a biased estimate of a parameter θ , decrease linearly

with sample size (a common situation). Suppose $E(\hat{\theta}) = \theta + \frac{B}{Nm}$ where Nm = sample size. Let $\hat{\theta}_0$ be an estimate of θ based on all Nm observations. Let $\hat{\theta}_1, \hat{\theta}_2, \dots, \hat{\theta}_N$ be a corresponding estimate based on $(N-1)m$ observations, and

$$E(\hat{\theta}_i) = \theta + \frac{B}{(N-1)m} .$$

Let

$$J_i(\hat{\theta}) = N\hat{\theta} - (N-1)\hat{\theta}_i .$$

Then

$$\begin{aligned} E(J_i(\hat{\theta})) &= NE(\hat{\theta}) - (N-1)E(\hat{\theta}_i) \\ &= N\left(\theta + \frac{B}{Nm}\right) - (N-1)\left(\theta + \frac{B}{(N-1)m}\right) \\ &= N\theta + \frac{B}{m} - (N-1)\theta - \frac{B}{m} \\ &= \theta \end{aligned}$$

$$J(\hat{\theta}) = \frac{1}{N} \sum_{i=1}^N J_i(\hat{\theta})$$

is the best unbiased estimate of θ with variance equal to

$$V(J(\hat{\theta})) = \frac{1}{N} V(J_i(\hat{\theta}))$$

and

$$J(\hat{\theta}) \underset{\sim}{\text{asymptotically}} N(\theta, V(J(\hat{\theta}))) .$$

For testing $H_0: \theta = 0$ vs $H_a: \theta \neq 0$, use the t statistic

$$t = \frac{\theta}{\sqrt{V(J(\theta))}} = \frac{J(\hat{\theta})}{\sqrt{V(J_{\hat{\theta}}(\hat{\theta}))/N}} .$$

The Jackknife procedure has the advantages of being usable on a relatively small data base and of theoretically adjusting for bias.

In applying this method to multiple regression, divide the sample data into N subsamples of equal size m . Based on the Stepwise Regression, investigate the first variable to enter into the equation and obtain N estimates of the parameters and the corresponding pseudo-value $J_{\hat{\theta}}(\hat{\theta})$ and $J(\hat{\theta})$ and use the t statistic to test the hypothesis regression coefficient is equal to zero against the alternative hypothesis that the regression coefficient is not equal to zero. If we reject the H_0 , the next step would be to investigate the second variable. Repeat the same procedure until we reject the H_0 of including a variable into the equation or alternately all variables to be considered are accepted at a statistically significant level to be included into the equation.

Final estimates of the parameters are obtained from the next to final step or final step if all variables considered are included in the equation.

D. PATTERN ANALYSIS

Identifying responses to items as correct or incorrect makes it possible to determine test scores by counting the number of items answered correctly. However, the total number of items answered correctly does not exhaust all the information contained in the responses. Different individuals may answer different combinations of items correctly although the total number of items answered correctly is the same. To each of these patterns, there corresponds a different possible score, called a pattern score. On a three-item test, for example, there are 8 different possible pattern scores. In contrast, there are only 4 different scores determinable by counting the number of items answered correctly. By creating a more refined and extensive measurement scale, pattern scores may produce higher validities than traditional total-correct scores [13].

Pattern scores are also possible for different patterns of any binary responses, including yes or no responses to items on a biographical inventory.

A computer program was developed by B.F. Folce Jr. [14] for his Master's thesis under the guidance of R.A. Weitzman. It is called Pattern Analysis Item Nominator (PAIN). PAIN operated by computing a mean criteria score for each pattern of responses in a given subset, assigning these scores to subjects having that pattern of responses, and correlating the assigned scores with the subject's actual criterion score.

IV. DATA PRESENTATION

A. GENERAL

The primary analysis of the data was conducted using three packaged computer programs at the W.R. Church Computer Center at the Naval Postgraduate School. These programs were the Statistical Package for the Social Sciences (SPSS) to provide Stepwise Multiple Regression as well as Pearson Correlations, BIMEDO3R to provide Multiple Regressions for the data within each selection of subsamples from the same population, and SNAP/IEDA to obtain scatter-plots of the data.

Two programs written by B.F. Folce were used in Pattern Analysis. The first program called Pattern Analysis Item Nominator (PAIN) provides the following information:

1. Validities of all item subsets examined.
2. A list of the items that form the most valid subset of a given size.
3. The validities of the most valid subset of each size.

The second program of Folce's was used to cross-validate the items selected by PAIN.

B. CRITERIA AND PREDICTORS

1. Criteria

The performance criterion used in this study was standardized QPR, denoted by ZQPR. This standardization was made to ensure that the differences among students would be

due to differing individual performances, eliminating possible effects related to quarters completed in the curriculum. It was derived by computing the mean QPR and its standard deviation for each input group. Individual ZQPR, then, was computed using its mean and standard deviation according to the input group.

Since the performance criterion used in this study was standardized QPR, the predicted QPR's were also in standard form. A conversion of these predicted ZQPR's back to raw QPR's was made using the conversion formula described below.

$$\text{PREDICTED QPR} = \text{MEAN QPR} + \frac{\text{SD.QPRX}(\text{PRED.ZQPR} - \text{MEAN PRED.ZQPR})}{\text{SD. PRED.ZQPR}}$$

2. Predictors

The original predictors were categorized into three groups as follows:

1. Self-reported biographical data.
2. Graduate Record Examination scores.
3. Strong Vocational Interest Blank Scores.

A new variable was derived denoted by INDEX, using self-reported baccalaureate QPR (BQPR) and college quality. BQPR was extracted by using the responses to questions 15 and 16 of the biographical questionnaire. Combinations of these two responses were converted to a four point QPR scale in the following manner:

<u>Answer to #15</u>	<u>Answer to #16</u>	<u>BQPR</u>
yes	no	3.70
no	yes	3.00
no	yes	2.30

College Quality is a rating of colleges and universities based on mean Scholastic Aptitude Test scores [15].

C. RESULT OF THE STUDY

All correlation coefficients and prediction equations presented subsequently in this section were determined from the validation sample (N = 50) and all cross-validation correlation coefficients were computed from the hold-out sample (N = 24). Throughout this section, only the results which were significant at or beyond the 0.10 level are reported and only correlation coefficients of 0.25 or higher are reported. Appendices A and B contain a complete list of the correlation coefficients obtained in this study.

The heading "Variable Entered" in the tables will list in order the variables as they came into the Stepwise Multiple Regression. The biographical questions were represented by ITEM ..., thus ITEM 11 represented biographical question number 11. The SVIB scales were represented by VAR ..., as listed in Appendix B.

1. Stepwise Multiple Regression

a. Biographical Data

Fifty-eight items from the biographical questionnaire were proposed to predict ZQPR. ITEM 55, ITEM 59 and

ITEM 60 were excluded from the investigation since even if these items entered into the equation, those items would have no use as predictors (not available at time of officer/student selection). Those items are listed as follows:

ITEM 55: Are you satisfied with your education at the Naval Postgraduate School?

ITEM 59: Do you like your degree curriculum?

ITEM 60: Would you choose a different degree curriculum if you could start over again?

The correlation coefficients displayed in Table 1 were calculated by the SPSS program using the Pearson Product-Moment correlation. The table contains the results of correlation between ZQPR and some of the Biographical questions.

TABLE I

CORRELATION COEFFICIENTS BETWEEN
ZQPR AND SOME BIOGRAPHICAL ITEMS

BIO ITEM #	CORR. COEFF.
ITEM 11	0.26
ITEM 14	-0.26
ITEM 15	0.34
ITEM 23	-0.32
ITEM 28	-0.26
ITEM 44	0.27
ITEM 48	0.26

Table II contains the summary result of the regression analysis together with cross-validation correlation coefficients determined by the SPSS program. Results only

up to the seventh step are reported in Table II. All together there were 14 items accepted to be included in the equation at a level of significance $\alpha = 0.05$, but only ITEM 15 yielded a cross-validation correlation greater than 0.25. Twelve percent of the total variation was explained by this item.

TABLE II

SUMMARY OF REGRESSION OF ZQPR ON BIOGRAPHICAL ITEMS

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	ITEM 15	6.329*	0.34	0.30
2	ITEM 19	4.740*	0.44	-0.04
3	ITEM 14	5.432*	0.53	0.04
4	ITEM 46	4.395*	0.59	0.06
5	ITEM 11	5.977*	0.65	0.18
6	ITEM 23	5.026*	0.70	0.15
7	ITEM 29	5.290*	0.74	0.16

Table III shows that the correlation coefficient between ZQPR and the variable INDEX was 0.30 and the cross-validation correlation coefficient was 0.55. Equation I shows the predicted ZQPR using the variable INDEX as predictor.

TABLE III

SUMMARY OF REGRESSION OF ZQPR ON INDEX

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	INDEX	4.600*	0.30	0.55

Equation I:

$$ZQPRP = -1.654 + 0.0027 \times \text{INDEX} .$$

The next step was to investigate the relationship between ZQPR, INDEX and the Biographical Items.

ITEM 15 and ITEM 16 were excluded from this step (together with three items already not in the analysis) since these two items had been used to compute the variable INDEX.

Table IV displays the result of the regression of ZQPR on INDEX and the remaining Biographical Data. It can be seen from Table IV that only two variables were significantly accepted in the equation at $\alpha \leq 0.05$. All the seven variables displayed in the table were significant at $\alpha \leq 0.10$. Equation II displays predicted ZQPR from the seven variables selected. The cross-validation correlation coefficient for this set of predictors is 0.44.

TABLE IV

SUMMARY OF REGRESSION OF ZQPR ON INDEX AND BIO ITEMS

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	ITEM 23	5.228*	0.32	0.03
2	ITEM 11	4.107*	0.42	0.19
3	ITEM 14	3.926**	0.49	0.24
4	INDEX	3.840**	0.55	0.39
5	ITEM 02	6.338**	0.63	0.42
6	ITEM 56	5.269**	0.68	0.44
7	ITEM 39	5.083**	0.72	0.44

Equation II:

$$ZQPRP = -2.89 - 0.610 \times (\text{ITEM } 23) + 0.621 \times (\text{ITEM } 11)$$

$$-0.651 \times (\text{ITEM } 14) + 0.003 \times (\text{INDEX}) + 0.934 \times (\text{ITEM } 0)$$

$$+0.700 \times (\text{ITEM } 56) + 0.427 \times (\text{ITEM } 39) .$$

Not all the items on the Biographical Questionnaire would be acceptable for use under current personnel policies; some have no face validity, or zero yes or zero no answers. Further analysis was done based on only those items which were considered to be useful for this study. These items are listed below.

QUESTION #	QUESTION
1.	Did you receive your commission from the USNA?
2.	Did you receive your commission through an ROTC program?
4.	Is your rank Navy Lieutenant or below?
5.	Are you a pilot or other flight officer?
6.	Are you a submarine officer?
7.	Are you an unrestricted line officer?
8.	Are you a staff officer?
9.	Do you have a B.S. (not a B.A.) degree?
10.	Have you had at least one year of College Calculus at an institution other than the Naval Postgraduate School?

QUESTION

QUESTION

11. Do you speak at least one language other than English?
12. Do you have a master's degree from a school other than the Naval Postgraduate School?
13. Have you taken any graduate courses other than at the Naval Postgraduate School?
14. Have you ever completed any courses at night school or through correspondence?
22. Was a branch of engineering your undergraduate major in college?
37. Did you take any College-Preparatory program in high school?
44. Are you younger than 30 years of age?
45. Would you expect to use any skills learned in graduate school in subsequent assignments in the Navy?
46. Do you expect to use any graduate education obtained while on active duty in work after you retire from the Navy?
61. Was at least part of your motivation to remain in the Navy the opportunity to receive postgraduate education?

The following tables show the summary results of the regression analysis conducted using the SPSS program.

The inclusion of the first four variables in the equation was significant at $\alpha \leq 0.05$. The F-test also accepted the inclusion of seven variables at $\alpha \leq 0.10$.

Equations III-A and III-B describe the four variables equation and the seven variables equation, respectively.

TABLE V

SUMMARY OF REGRESSION OF ZQPR ON INDEX AND
SELECTED BIO ITEMS

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	ITEM 14	4.901*	0.31	0.18
2	INDEX	5.369*	0.43	0.43
3	ITEM 02	4.431*	0.51	0.48
4	ITEM 11	4.736*	0.58	0.50
5	ITEM 12	3.760**	0.62	0.50
6	ITEM 46	3.631**	0.66	0.50
7	ITEM 13	3.463**	0.70	0.57

Equation III-A:

$$\begin{aligned} \text{ZQPRP} = & -2.079 - 0.748 \text{ X (ITEM14)} + 0.003 \text{ X (INDEX)} \\ & + 0.738 \text{ X (ITEM02)} + 0.540 \text{ X (ITEM11)} . \end{aligned}$$

Equation III-B:

$$\begin{aligned} \text{ZQPRP} = & -3.751 - 0.884 \text{ X (ITEM 14)} + 0.004 \text{ X (INDEX)} \\ & + 0.738 \text{ X (ITEM 02)} + 0.805 \text{ X (ITEM 11)} \\ & + 1.016 \text{ X (ITEM 12)} + 1.402 \text{ X (ITEM 46)} \\ & + 0.554 \text{ X (ITEM 13)} . \end{aligned}$$

Equation III-A yielded a 0.58 correlation in validation and a 0.50 correlation in the cross-validation sample, and Equation III-B yielded a 0.70 in validation and a 0.57 in cross-validation.

The negative weight of ITEM 14 shows that a student who gave a "no" answer to this item had a better academic performance than a student who gave a "yes". However, even if this item happens to be a good predictor for academic performance, this information might not be available on an officer's record. Thus further analysis was performed by excluding ITEM 14. Table VI displays the summary results of this analysis.

TABLE VI

SUMMARY OF REGRESSION OF ZQPR ON INDEX AND
SELECTED BIO ITEMS (EXCLUDING ITEM 14)

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	INDEX	4.602*	0.30	0.55
2	ITEM 02	3.905**	0.39	0.56
3	ITEM 04	3.236**	0.45	0.52
4	ITEM 11	3.650**	0.51	0.51
5	ITEM 12	3.843**	0.57	0.51

Equation IV:

$$\begin{aligned}
 \text{ZQPR} = & -2.369 + 0.003 \text{ X (INDEX)} + 0.761 \text{ X (ITEM 02)} \\
 & + 0.551 \text{ X (ITEM 04)} + 0.549 \text{ X (ITEM 11)} \\
 & + 1.630 \text{ X (ITEM 12)}.
 \end{aligned}$$

Only INDEX was accepted to be included in the equation at $\alpha \leq 0.05$. Five variables were significant at $\alpha \leq 0.10$.

Equation IV shows predicted ZQPR with five variables. The validation correlation of Equation IV was 0.59 and the cross-validation between predicted ZQPR and actual ZQPR for Equation IV was 0.51.

b. Graduate Record Examination

A total of 498 NPS students took the Graduate Record Exam, including 80 students registered in the Operations Research/Systems Analysis curriculum.

The following table shows some descriptive statistics for the GRE data.

TABLE VII
DESCRIPTIVE STATISTICS FOR THE GRE DATA

STATISTICS	QUANTITATIVE		VERBAL	
	N = 498	N = 80	N = 498	N = 80
MEAN	660.02	711.74	532.10	549.62
MEDIAN	680.00	715.00	530.00	540.00
VARIANCE	6500.00	3569.00	9949.00	9596.00
S.D.	80.60	59.70	99.70	97.90
RANGE	440.00	290.00	590.00	480.00
MAX	820.00	820.00	830.00	790.00
MIN	380.00	530.00	240.00	310.00

Table VIII contains the correlation coefficients between ZQPR and GRE-Quantitative, GRE-Verbal and GRE-Total.

TABLE VIII
CORRELATION BETWEEN ZQPR AND GRE
(N = 50)

GRE	CORRELATION COEFFICIENT
QUANTITATIVE	0.45
VERBAL	0.41
TOTAL (QUANT + VERB)	0.49

Table IX contains the summary results of a regression of ZQPR on GRE scores.

Equation V shows the constant and variable weights for this predictor system. The cross-validation correlation coefficient of the predicted ZQPR was 0.69.

TABLE IX
SUMMARY FROM REGRESSION OF ZQPR ON GRE SCORES
(N = 50)

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	QUANT	12.034*	0.45	0.55
2	VERBAL	3.376**	0.50	0.69

Equation V:

$$\text{ZQPR} = -5.271 + 0.054 \text{ X (GRE QUANT)} + 0.026 \text{ X (GRE VERB)}$$

c. SVIB Scales

Table X contains the correlation coefficients of ZQPR with SVIB scales which are ≥ 0.25 .

TABLE X
CORRELATION COEFFICIENTS BETWEEN
ZQPR AND SOME SVIB SCALES
(N = 74)

SVIB SCALE	CORRELATION COEFFICIENT
PHYSICAL THERAPIST	-0.27
VETERINARIAN	-0.37
PSYCHOLOGIST	0.36
MATHEMATICIAN	0.39
CHEMIST	0.26
FOREST SERVICE	-0.33
POLICEMAN	-0.31
YMCA SECRETARY	-0.36
RECREATION ADMINISTRATOR	-0.26
CPA OWNER	0.31
SENIOR CPA	0.33
MORTICIAN	0.31
COMPUTER PROGRAMMER	0.37
ACADEMIC ACHIEVEMENT	0.32
SPECIALIZATION LEVEL	0.32

The summary results of the regression of ZQPR on the SVIB scales is shown in Table XI. It can be seen that the four predictor system was significant at $\alpha \leq 0.05$ and the six predictor system was significant at $\alpha \leq 0.10$.

The equation for four predictor systems and six predictor system are described by Equation VI-A and VI-B, respectively. Equation VI-A yielded a 0.67 correlation coefficient in the validation sample and a cross-validation

correlation of 0.52. Equation VI-B yielded a 0.73 correlation in validation sample and a cross-validation correlation of 0.59.

TABLE XI
SUMMARY OF REGRESSION OF ZQPR ON SVIB SCALES

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	VAR 19	8.379*	0.39	0.20
2	VAR 55	8.988*	0.54	0.37
3	VAR 27	4.806*	0.60	0.45
4	VAR 14	7.490*	0.67	0.52
5	VAR 26	3.058**	0.70	0.57
6	VAR 60	3.418**	0.73	0.59

Equation VI-A:

$$\begin{aligned} \text{ZQPR} = & 2.234 - 0.023 \text{ X (VAR 19)} + 0.042 \text{ X (VAR 55)} \\ & - 0.057 \text{ X (VAR 27)} - 0.060 \text{ X (VAR 14)} \end{aligned}$$

Equation VI-B

$$\begin{aligned} \text{ZQPR} = & 1.059 - 0.022 \text{ X (VAR 19)} + 0.025 \text{ X (VAR 55)} \\ & - 0.093 \text{ X (VAR 27)} - 0.070 \text{ X (VAR 14)} \\ & + 0.047 \text{ X (VAR 26)} + 0.034 \text{ X (VAR 60)}. \end{aligned}$$

d. GRE and Selected Biographical Items

The combination of selected items from the biographical inventory and the Graduate Record Exam was

analyzed to see whether this combination could provide any information about academic performance. The following table shows the summary results from the regression of ZQPR on GRE and selected biographical items. Equation VII predicts ZQPR with five predictors. These five variables are significant at $\alpha \leq 0.05$. The correlation coefficient was 0.72 and the cross-validation correlation coefficient was 0.64.

TABLE XII
SUMMARY OF REGRESSION OF ZQPR ON GRE
AND SELECTED BIO ITEMS

STEP	VAR. ENTERED	FVALUE	MULT.R	X-VALIDATION
1	GRE TOTAL	13.977*	0.48	0.69
2	ITEM 14	7.911*	0.59	0.60
3	ITEM 11	4.638*	0.64	0.61
4	ITEM 02	4.627*	0.68	0.61
5	INDEX	4.537*	0.72	0.64

Equation VII:

$$\begin{aligned} \text{ZQPRP} = & -5.409 + 0.032 \text{ X (GRE TOTAL)} - 0.788 \text{ X (ITEM 14)} \\ & + 0.514 \text{ X (ITEM 11)} + 0.736 \text{ X (ITEM 02)} \\ & + 0.002 \text{ X (INDEX)}. \end{aligned}$$

As can be seen from Equation VII, ITEM 14 was again included in the equation with a negative weight. Removing ITEM 14 from the set of candidates for predictors

yielded the results as shown in Table XIII and Equation VIII. Only three predictors were significant. The correlations in validation and in cross-validation were 0.60 and 0.66 respectively.

TABLE XIII
SUMMARY OF REGRESSION OF ZQPR ON GRE
AND SELECTED BIO ITEMS
(EXCLUDING ITEM 14)

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	GRE TOTAL	13.977*	0.48	0.69
2	ITEM 44	4.732*	0.55	0.64
3	ITEM 13	3.772*	0.60	0.66

Equation VIII:

$$\text{ZQPR} = -4.322 + 0.031 \text{ X (GRE TOTAL)} + 0.653 \text{ X (ITEM 44)} \\ + 0.593 \text{ X (ITEM 13)}.$$

Table XIV, together with Equation IX, displays the results if INDEX was forced into the equation.

TABLE XIV

SUMMARY OF REGRESSION OF ZQPR ON GRE
SELECTED BIO ITEMS (EXCLUDING ITEM 14)
AND INDEX (FORCED)

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	INDEX	4.602*	0.30	0.55
2	GRE TOTAL	10.596*	0.51	0.72
3	ITEM 04	3.495**	0.56	0.68
4	ITEM 02	4.981**	0.62	0.66
5	ITEM 11	4.196**	0.66	0.66

Equation IX:

$$\begin{aligned} \text{ZQPRP} = & -5.652 + 0.0015 \text{ X (INDEX)} + 0.031 \text{ X (GRE TOTAL)} \\ & + 0.637 \text{ X (ITEM 04)} + 0.720 \text{ X (ITEM 02)} \\ & + 0.471 \text{ X (ITEM 11)}. \end{aligned}$$

e. GRE and SVIB

The following table (Table XV) presents the results of the step-wise regression for the combination of GRE scores and SVIB scales. It can be seen from the table that the multiple correlation coefficient attained with four predictors was 0.69; yielded a cross-validation correlation coefficient of 0.64. Equation X shows the weight for each predictor.

TABLE XV
SUMMARY OF REGRESSION OF ZQPR ON SVIB-GRE

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	GRE TOTAL	13.977*	0.48	0.69
2	VAR 38	5.150*	0.55	0.78
3	VAR 11	6.988*	0.63	0.79
4	VAR 41	6.269*	0.69	0.64
5	VAR 40	3.839**	0.72	0.61

Equation X:

$$\begin{aligned} \text{ZQPRP} = & -5.586 + 0.020 \text{ X (GRE TOTAL)} + 0.010 \text{ X (VAR 38)} \\ & + 0.064 \text{ X (VAR 11)} + 0.041 \text{ X (VAR 41)}. \end{aligned}$$

As can be seen, INDEX was not strong enough to be included in the equation. Forcing INDEX into the equation yielded the results shown in Table XVI and Equation XI.

TABLE XVI
SUMMARY OF REGRESSION OF ZQPR ON SVIB, GRE
AND INDEX (FORCED)

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	INDEX	4.602*	0.30	0.55
2	GRE TOTAL	10.596*	0.51	0.72
3	VAR 55	5.160*	0.60	0.73
4	VAR 19	5.458*	0.64	0.64

Equation XI:

$$\begin{aligned} \text{ZQPRP} = & -4.234 + 0.002 \text{ X (INDEX)} + 0.019 \text{ X (GRE TOTAL)} \\ & + 0.028 \text{ X (VAR 55)} - 0.021 \text{ X (VAR 19)} . \end{aligned}$$

f. Selected BIO - SVIB

The following table presents the results of the stepwise regression for the combination of selected biographical items and SVIB scales, including INDEX. Equation XII shows the weight for each predictor. The correlation attained was 0.77, and the cross-validation was 0.50

TABLE XVII
SUMMARY OF REGRESSION OF ZQPR ON SVIB
SCALES AND SELECTED BIO ITEMS

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	VAR 19	8.379*	0.39	0.20
2	VAR 55	8.988*	0.54	0.37
3	VAR 27	4.806*	0.60	0.45
4	VAR 14	7.490*	0.67	0.52
5	ITEM 44	5.878*	0.72	0.51
6	ITEM 12	8.593*	0.77	0.50

Equation XII:

$$\begin{aligned} \text{ZQPRP} = & 2.185 - 0.020 \text{ X (VAR 19)} + 0.040 \text{ X (VAR 55)} \\ & - 0.062 \text{ X (VAR 27)} - 0.063 \text{ X (VAR 14)} \\ & + 0.563 \text{ X (ITEM 44)} + 1.897 \text{ X (ITEM 12)} . \end{aligned}$$

It can be seen that INDEX was not included in Equation XII. Forcing INDEX into the equation yielded the following results:

TABLE XVIII
SUMMARY OF REGRESSION OF ZQPR ON
SVIB - BIO - INDEX (FORCED)

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	INDEX	4.602*	0.30	0.55
2	VAR 55	7.895*	0.47	0.64
3	VAR 19	8.951*	0.59	0.53
4	ITEM 12	3.939**	0.64	0.52
5	VAR 27	4.477**	0.68	0.57
6	VAR 14	8.307**	0.74	0.61
7	ITEM 44	5.498**	0.78	0.54

Equation XIII:

$$\begin{aligned}
 ZQPRP = & 1.690 + 0.001 \times (\text{INDEX}) + 0.040 \times (\text{VAR 55}) \\
 & - 0.019 \times (\text{VAR 19}) + 1.852 \times (\text{ITEM 12}) \\
 & - 0.061 \times (\text{VAR 27}) - 0.062 \times (\text{VAR 14}) \\
 & + 0.052 \times (\text{ITEM 44}) .
 \end{aligned}$$

g. All Variables

Table XIX, together with Equation SIV, displays the results of regressing ZQPR on all candidates for predictors. The multiple correlation attained with 6 predictors was 0.74, and yielded a cross-validation correlation coefficient of 0.60.

TABLE XIX
SUMMARY OF REGRESSION OF ZQPR
ON ALL VARIABLES

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	GRE TOTAL	13.977*	0.48	0.69
2	VAR 38	5.150*	0.55	0.78
3	VAR 11	6.988*	0.63	0.79
4	VAR 41	6.269*	0.69	0.64
5	ITEM 04	3.986**	0.72	0.60
6	ITEM 22	3.044**	0.74	0.60

Equation XIV:

$$\begin{aligned}
 \text{ZQPRP} = & -6.349 + 0.019 \text{ X (GRE TOTAL)} + 0.008 \text{ X (VAR 38)} \\
 & + 0.071 \text{ X (VAR 11)} + 0.050 \text{ X (VAR 41)} \\
 & + 0.548 \text{ X (ITEM 04)} + 0.375 \text{ X (ITEM 22)} .
 \end{aligned}$$

Forcing INDEX into the equation yielded the results presented in Table XX and Equation XV. The multiple correlation coefficient attained with seven predictors was 0.78 and the cross-validation correlation was 0.70.

TABLE XX

SUMMARY OF REGRESSION OF ZQPR ON
ALL VARIABLES WITH INDEX FORCED
INTO THE EQUATION

STEP	VAR. ENTERED	FVALUE	MULT. R	X-VALIDATION
1	INDEX	4.602*	0.30	0.55
2	GRE TOTAL	10.596*	0.51	0.72
3	ITEM 14	8.250*	0.61	0.53
4	VAR 38	7.311*	0.72	0.70
5	ITEM 02	5.588*	0.73	0.70
6	VAR 07	4.170*	0.75	0.60
7	ITEM 13	4.939*	0.78	0.70

Equation SV:

$$\begin{aligned}
 \text{ZQPRP} = & -6.773 + 0.002 \text{ X (INDEX)} + 0.027 \text{ X (GRE TOTAL)} \\
 & - 0.693 \text{ X (ITEM 14)} + 0.037 \text{ X (VAR 38)} \\
 & + 0.600 \text{ X (ITEM 02)} + 0.024 \text{ X (VAR 07)} \\
 & + 0.532 \text{ X (ITEM 13)} .
 \end{aligned}$$

2. Summary Results from the Stepwise Regression Analysis

Stepwise regression using biographical information, the Strong vocational interest Blank and the Graduate Record Examination yielded several prediction equations which produced significant results in cross-validation.

Four of these performance prediction equations were selected for further discussion in the subsequent paragraphs. Their selection was based on the number of predictors involved

and on the correlation coefficients attained in the validation and cross-validation samples. These four systems of predictors are:

- a. A combination of GRE and SVIB, consisting of four predictors, all of which were significant at $\alpha \leq 0.05$.
- b. A combination of GRE and BIO items, consisting of five predictors, all of which were significant at $\alpha \leq 0.05$.
- c. A combination of SVIB and BIO items, consisting of six predictors, all of which were significant at $\alpha \leq 0.05$.
- d. A combination of GRE, SVIB and BIO items, consisting of seven predictors, all of which were significant at $\alpha \leq 0.05$.

Each of these systems of predictors for academic performance is briefly discussed in the following paragraphs.

a. A Combination of GRE and SVIB Scores

The set of predictors for academic performance composed of a combination of GRE scores and SVIB scores produced a 0.69 validation correlation and a 0.64 cross-validation correlation. Table XXI displays the constant, the variables and the weights for the prediction equation described by Equation X.

TABLE XXI
COMBINATION OF GRE - SVIB

VARIABLES	DESCRIPTION	WEIGHT
GRE TOTAL	GRE VERBAL + GRE QUANT	+0.020
VAR 38	CPA OWNER	+0.010
VAR 11	MATHEMATICIAN	+0.064
VAR 41	CREDIT MANAGER	+0.041
CONSTANT		-5.586

The formula for converting predicted ZQPR to raw QPR is provided by Equation XVI.

Equation XVI:

$$\text{PRED. RAW QPR} = 0.456 \times (\text{PRED. ZQPR}) + 3.30 .$$

b. A Combination of GRE Scores and BIO Data

The set of predictors for academic performance composed of a combination of GRE scores and of BIO items produced a 0.72 validation correlation and a 0.64 cross-validation correlation. Table XXII displays the constant, the variables and the weights for the prediction equation described by Equation VII.

TABLE XXII
COMBINATION OF GRE - BIO

VARIABLES	DESCRIPTION	WEIGHT
GRE TOTAL	GRE VERBAL + GRE QUANT	+ 0.032
ITEM 14	COMPLETED NIGHT SCHOOL (OR THROUGH CORRESP)	- 0.788
ITEM 11	SPEAK AT LEAST ONE LANGUAGE OTHER THAN ENGLISH	+ 0.514
ITEM 02	ROTC GRADUATE	+ 0.736
INDEX	BQPR X COLL. QUALITY	+ 0.002
CONSTANT		- 5.409

The formula for converting predicted ZQPR to raw QPR is provided by Equation XVII.

Equation XVII:

$$\text{PRED. RAW QPR} = 0.337 \times (\text{PRED. ZQPR}) + 3.41$$

c. A combination of SVIB Scores and BIO Data

The set of predictors for academic performance composed of a combination of SVIB scores and BIO items produced a 0.77 validation correlation and a 0.50 cross-validation correlation. Table XXIII displays the constant, the variables and the weights for the prediction equation described by Equation XII.

TABLE XXIII
COMBINATION OF SVIB - BIO

VARIABLES	DESCRIPTION	WEIGHT
VAR 19	FOREST SERVICE	- 0.020
VAR 55	COMPUTER PROGRAMMER	+ 0.039
VAR 27	YMCA SECRETARY	- 0.062
VAR 14	ENGINEER	- 0.063
ITEM 44	YOUNGER THAN 30 YEARS	+ 0.563
ITEM 12	POSSESSING MASTER'S DEGREE	+ 1.897
CONSTANT		+ 2.185

The formula for converting predicted ZQPR to raw QPR is provided by Equation XVIII.

Equation XVIII:

$$\text{PRED. RAW QPR} = 0.346 \times (\text{PRED. ZQPR}) + 3.38$$

d. A combination of GRE, SVIB and BIO Data

The set of predictors for academic performance composed of a combination of GRE scores, SVIB scores and BIO items produced a 0.78 validation correlation and a 0.70 cross-validation correlation. Table XXIV displays the constants, the variables and the weights for the prediction equation described by Equation XV.

TABLE XXIV
COMBINATION OF GRE - SVIB - BIO

VARIABLES	DESCRIPTION	WEIGHT
INDEX	BQPR X COLL.QUALITY	+ 0.002
GRE TOTAL	GRE VERBAL + GRE QUANT	+ 0.027
ITEM 14	COMPLETED NIGHT SCHOOL OR THROUGH CORRESP.	- 0.693
VAR 38	CPA OWNER	+ 0.037
ITEM 02	ROTC GRADUATE	+ 0.598
VAR 07	PHYSICIAN	+ 0.024
ITEM 13	HAVE TAKEN GRADUATE COURSE OTHER THAN AT NPS	+ 0.532
CONSTANT		- 6.773

The formula for converting predicted ZQPR to raw QPR is provided by Equation XVIX.

Equation XVIX:

$$\text{PRED. RAW QPR} = 0.318 \times (\text{PRED. ZQPR}) + 3.39$$

3. Jackknifing

The four equations that had been selected were further studied to obtain the regression coefficients using the Jackknife procedure. The regression coefficients obtained from this procedure were used to compute the correlation coefficient and were then compared with the results obtained from the Stepwise Multiple Regression. The procedure for Jackknifing is presented in the previous chapter. In this study, the validation sample was divided into ten subsamples, each with five cases.

The following table presents the comparisons between the regression coefficients obtained from using Stepwise Multiple Regression and the Jackknife procedure.

It can be seen from the table that there are no significant differences between estimators obtained from the Stepwise Multiple Regression and the Jackknife procedure. We are on firmer ground in concluding that the variable's weights in this study are unviased and in concluding that it is no longer necessary to assume that the error is normally distributed.

4. Expectancy Charts

In order to more easily visualize the results from this study, expectancy charts were derived, using the prediction equations obtained from the Jackknife method and the conversion formula.

An expectancy chart is defined as a table of numbers from which one may determine the likelihood or probability that a particular individual or group of individuals will attain a specified definition of "superiority" [16]. There are two types of expectancy charts: institutional and individual. The institutional expectancy chart indicates what will happen, institutionally, if a particular minimum cutting score is applied. For example, a minimum cutting score of 3.60 will yield 87% who are "superior". The individual expectancy chart is designed to determine the likelihood or probability that a specific individual will achieve "superiority", given his score.

TABLE XXV

COMPARISON BETWEEN ESTIMATORS OBTAINED FROM THE STEPWISE
MULTIPLE REGRESSION (SMR) AND THE JACKKNIFE PROCEDURE

VARIABLES	SMR	WEIGHT JACKKNIFE
a. Combination of GRE - SVIB		
GRE TOTAL	+0.02034	+0.023277
VAR 38	+0.01007	+0.009545
VAR 11	+0.06399	+0.059148
VAR 41	+0.04053	+0.03623
CONSTANT	-5.58609	-5.68205
VALIDATION CORR. COEFF.	0.68908	0.7006
X-VALIDATION	0.6435	0.6613
b. Combination of GRE - SVIB		
GRE TOTAL	+0.03169	+0.031186
ITEM 14	-0.78837	-0.031186
ITEM 11	+0.51393	+0.504795
ITEM 02	+0.73564	+0.802268
INDEX	+0.00224	+0.002285
CONSTANT	-5.50924	-5.401033
VALIDATION CORR. COEFF.	0.71554	0.7147
X-VALIDATION CORR. COEFF.	0.6368	0.6385
c. Combination of SVIB - BIO		
VAR 19	-0.01989	-0.0224
VAR 55	+0.03945	+0.03578
VAR 27	-0.06236	-0.05398
VAR 14	-0.06290	-0.04654
ITEM 44	+0.56286	+0.55097
ITEM 12	+1.89703	+1.8484
CONSTANT	+2.18459	+1.7253
VALIDATION CORR. COEFF.	0.77439	0.7773
X-VALIDATION CORR. COEFF.	0.5066	0.5091
d. Combination of SVIB-BIO-GRE		
INDEX	+0.00231	+0.002301
GRE TOTAL	+0.02736	+0.02654
ITEM 14	-0.69271	-0.68273
VAR 38	+0.03732	+0.038643
ITEM 02	+0.59807	+0.655238
VAR 07	+0.02425	+0.02627
ITEM 13	+0.53236	+0.57942
CONSTANT	-6.77349	-6.79821
VALIDATION CORR. COEFF.	0.78393	0.7831
X-VALIDATION CORR. COEFF.	0.7021	0.6976

"Superiority" is defined as the level of academic performance of a student who had a QPR greater than or equal to a median QPR of the 74 subjects in this study.

5. Pattern Analysis

Pattern analyses were conducted using Biographical Questionnaire data from the validation group. The results then were cross-validated on the hold-out group.

The first item selected was ITEM 17 and yielded a 0.27 correlation coefficient with the criterion score: the second item selected was ITEM 12 and together with ITEM 17 yielded a 0.44 correlation with the criterion score. The third item selected was ITEM 5. The three items selected produced a 0.53 correlation coefficient. The cross-validation correlation coefficient for the three items selected was -0.014, which is not significant. The reduction in correlation was probably due to the relatively small samples in the validation and hold-out samples. There were no subjects who had the yes - yes - no pattern in the validation group, hence a pattern score could not be computed, and a zero pattern score was assigned to that pattern, while in the cross-validation sample there were two subjects who had that pattern. This caused the correlation coefficient to drop significantly in the validation sample.

EXPECTANCY CHARTS






GROUP	MIN SCORE	PERCENTAGE THAT WILL BE SUPERIOR	
20%	3.62		80%
40%	3.41		60%
60%	3.20		40%
80%	3.02		20%
ALL	2.68		0%

Fig. 1 - a. Institutional expectancy chart based on combination of GRE - SVIB.

Conversion formula: Raw QPRP = 0.5022 X (ZQPRP) + 3.32





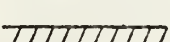
TABLE SCORE	CHANCES IN A HUNDRED OF BEING SUPERIOR	
3.64 - 4.00		80
3.41 - 3.61		60
3.20 - 3.40		40
3.02 - 3.19		20
2.68 - 3.01		0

Fig. 1 - b. Individual expectancy chart based on combination of GRE - SVIB.

Conversion formula: Raw QPRP = 0.5022 X (ZQPRP) + 3.32






GROUP	MIN SCORE	PERCENTAGE THAT WILL BE SUPERIOR
20%	3.63	 93%
40%	3.39	 83%
60%	3.20	 71%
80%	3.02	 59%
ALL	2.19	 49%

Fig. 2 - a. Institutional expectancy chart based on combination of
GRE - BIO.
Conversion formula: Raw QPRP = 0.4917 X (ZQPRP) + 3.34






TABLE SCORE	CHANCES IN A HUNDRED OF BEING SUPERIOR
3.63 - 4.00	 93
3.39 - 3.62	 73
3.20 - 3.38	 47
3.02 - 3.19	 21
2.19 - 3.01	 7

Fig. 2 - b. Individual expectancy chart based on combination of
GRE - BIO.
Conversion formula: Raw QPRP = 0.4917 X (ZQPRP) + 3.34






GROUP	MIN SCORE	PERCENTAGE THAT WILL BE SUPERIOR	
20%	3.66		87%
40%	3.37		77%
60%	3.21		64%
80%	3.06		60%
ALL	2.55		50%

Fig. 3 - a. Institutional expectancy chart based on combination of SVIB - BIO.

Conversion formula: Raw QPRP = $0.4541 \times (ZQPRP) + 3.31$






TABLE SCORE	CHANCES IN A HUNDRED OF BEING SUPERIOR	
3.66 - 4.00		87
3.37 - 3.65		67
3.21 - 3.36		46
3.06 - 3.20		40
2.55 - 3.06		7

Fig. 3 - b. Individual expectancy chart based on combination of SVIB - BIO.

Conversion formula: Raw QPRP = $0.4541 \times (ZQPRP) + 3.31$






GROUP	MIN SCORE	PERCENTAGE THAT WILL BE SUPERIOR
20%	3.64	 93%
40%	3.43	 83%
60%	3.20	 67%
80%	3.01	 59%
ALL	2.31	 50%

Fig. 4 - a. Institutional expectancy chart based on combination of SVIB - BIO - GRE.

Conversion formula: Raw QPRP = 0.3826 X (ZQPRP) + 3.35






TABLE SCORE	CHANCES IN A HUNDRED OF BEING SUPERIOR
3.64 - 4.00	 93%
3.43 - 3.63	 73%
3.20 - 3.42	 40%
3.01 - 3.19	 29%
2.31 - 3.00	 14%

Fig. 4 - b. Individual expectancy chart based on combination of SVIB - BIO - GRE.

Conversion formula: Raw QPRP = 0.3826 X (ZQPRP) + 3.35

V. CONCLUSION AND RECOMMENDATION

A. CONCLUSION

1. Four prediction equations for predicting academic performance have been developed in this study, using Biographical Questionnaire (including prior academic performance), Strong Vocational Interest Blank and Graduate Record Examination data.

2. Data from these three instruments, as well as data from any combination of two (or three) of them provided a higher potential for predicting academic performance than from using prior academic performance, as measured by self-reported undergraduate QPR and College Quality.

3. The 74 U.S. Navy officers in the sample group had already been subjected to screening processes, hence they were a more homogeneous group than U.S. Navy officers in general. This created a complexity that one cannot explore fully. For example, the Educational Potential Classification requires an over-all average grades at least 2.50 for direct input into a technical curriculum. This requirement reduced the variability of Baccalaureate QPR within the group and hence the INDEX. Under these circumstances the correlation of INDEX with the criterion score was reduced. Its true value would not have been changed, but the evidence available would not have permitted to see that value. Those who would

have failed because of the low prior academic performance would have been cut off at the source [3].

B. RECOMMENDATIONS FOR FURTHER RESEARCH

1. Other types of predictors, such as actual Baccalaureate QPR, grades in mathematics courses or other courses related to Operations Research/Systems Analysis, might be of interest.

2. Check the predictive validity of the predictor system developed in this study with a subsequent sample group, as was suggested by Sofge [8].

APPENDIX A

BIOGRAPHICAL QUESTIONNAIRE

<u>Biographical Question</u>	<u>Yes/No</u>	<u>Corr. with ZQPR</u>
1. Did you receive your commission from the USNA?	29/45	0.06
2. Did you receive your commission through an ROTC program?	15/59	0.12
3. Have you ever been an enlisted man in any service?	26/48	-0.19
4. Is your rank Navy Lieutenant or below?	55/19	0.21
5. Are you a pilot or other flight officer?	27/47	0.04
6. Are you a submarine officer?	3/71	-0.04
7. Are you an unrestricted line officer?	61/13	0.07
8. Are you a staff officer?	11/63	-0.10
9. Do you have a B.S. (not a B.A.) degree?	59/15	-0.03
10. Have you had at least one year of college calculus at an institution other than the Naval Postgraduate School?	68/6	0.04
11. Do you speak at least one language other than English?	25/49	0.26
12. Do you have a master's degree from a school other than the Naval Postgraduate School?	1/73	0.21
13. Have you taken any graduate courses other than at the Naval Postgraduate School?	15/59	0.22
14. Have you ever completed any courses at night school or through correspondence?	32/42	-0.26

<u>Biographical Questions</u>	<u>Yes/No</u>	<u>Corr. with ZQPR</u>
15. As an undergraduate in college, did you have an A or A-average?	7/67	0.34
16. Was your undergraduate average in college below B?	25/49	-0.17
17. Do you need to wear glasses for reading?	19/55	-0.16
18. Are you five feet nine inches or shorter?	17/57	-0.17
19. Are you 172 pounds or heavier?	48/26	0.21
20. Are you white (Caucasian)?	74/ 0	--
21. Are you black (Negro)?	0/74	--
22. Was a branch of engineering your undergraduate major in college?	29/45	-0.07
23. Are you Roman Catholic?	18/57	-0.32
24. Are you Protestant?	47/27	0.20
25. Have you ever been divorced?	5/69	-0.08
26. Are you married now?	64/10	-0.11
27. Do you have any sons?	40/34	0.10
28. Do you have any daughters?	38/36	-0.26
29. Do you have any older brothers or sisters?	34/40	-0.00
30. Do you have any younger brothers or sisters?	54/20	-0.09
31. Is your father a college graduate?	29/45	-0.02
32. Has your mother ever attended college?	29/45	-0.003
33. Do you have a wife who is a college graduate?	30/44	0.13
34. Is or was your father a career military officer?	9/65	0.11

<u>Biographical Questions</u>	<u>Yes/No</u>	<u>Corr. with ZQPR</u>
35. Is or was your father a career enlisted man?	9/69	-0.15
36. Did you spend more than one year of your childhood on a farm?	16/58	-0.02
37. Did you take a college preparatory program in high school?	64/10	-0.19
38. Were you in the upper one-quarter of the college preparatory program in high school?	52/22	0.05
39. Do you smoke cigarettes, cigars or pipes?	33/41	0.14
40. Are you currently a student at any graduate school other than the Naval Postgraduate School?	0/74	--
41. Are you a student at the Naval Postgraduate School?	73/1	-0.02
42. Would you say that you typically drink an alcoholic beverage daily other than at mealtime?	20/54	0.09
43. Do you typically drink more than five cups of coffee a day?	20/54	-0.21
44. Are you younger than 30 years of age?	37/37	0.27
45. Would you expect to use any skills learned in graduate school in subsequent assignments in the Navy?	72/ 2	0.07
46. Do you expect to use any graduate education obtained while on active duty in work after you retire from the Navy?	70/ 4	0.03
47. Do you wish to serve in a billet requiring the education that you would receive at a graduate school?	65/ 9	0.26
48. Would you prefer to do your graduate work at a school other than the Naval Postgraduate School?	29/45	0.26

<u>Biographical Questions</u>	<u>Yes/No</u>	<u>Corr. with ZQPR</u>
49. Do you believe that postgraduate education will increase your chances for promotion?	57/17	-0.19
50. Were you last designated a principle or an alternate (as opposed to neither) by the Postgraduate Selection Board?	59/15	0.17
51. Have you ever been a patrol leader or a senior patrol leader in the Boy Scouts?	23/51	0.08
52. Have you ever been a Star Scout or above in the Boy Scouts?	23/51	0.15
53. Have you ever taken lessons for a musical instrument for longer than two consecutive years?	34/40	0.02
54. Do you now play a musical instrument?	11/63	0.08
55. Are you satisfied with your education at the Naval Postgraduate School?	64/10	
56. Are you or were you in the curriculum of your first or second choice?	64/10	0.11
57. Were you ever in the baccalaureate program?	3/71	0.06
58. Have you ever spent time in the engineering science curriculum?	35/39	-0.02
59. Do you now like your degree curriculum?	63/11	
60. Would you choose a different degree curriculum if you would start over again?	14/60	
61. Was at least part of your motivation to remain in the Navy the opportunity to receive postgraduate education?	40/34	-0.13

APPENDIX B
STRONG VOCATIONAL INTEREST BLANK

<u>Scale</u>	<u>Mean Std.Score</u>	<u>S.D.</u>	<u>Corr. with ZQPR</u>
1. Naval Officer	50.18	10.52	0.03
2. Physical Therapist	35.58	12.18	-0.27
3. Dentist	21.80	10.87	-0.09
4. Osteopath	26.03	11.62	-0.21
5. Veterinarian	23.78	9.79	-0.37
6. Physician	25.47	11.73	-0.08
7. Psychiatrist	23.92	11.04	0.12
8. Psychologist	28.01	9.59	0.36
9. Biologist	26.24	12.70	0.14
10. Architect	24.95	10.84	0.11
11. Mathematician	20.50	11.75	0.39
12. Physicist	21.68	13.06	0.23
13. Chemist	30.65	14.32	0.26
14. Engineer	28.82	11.40	0.16
15. Production Manager	39.82	8.64	0.00
16. Army Officer	42.38	10.79	-0.06
17. Air Force Officer	41.78	9.79	-0.02
18. Carpenter	22.80	13.08	-0.07
19. Forest Service	23.61	13.59	-0.33
20. Farmer	30.28	11.06	-0.20
21. Math-Science Teacher	31.27	9.83	0.03

<u>Scale</u>	<u>Mean Std.Score</u>	<u>S.D.</u>	<u>Corr. with ZQPR</u>
22. Printer	25.64	8.88	-0.01
23. Policeman	21.88	7.92	-0.31
24. Personnel Director	30.77	13.80	0.07
25. Public Administrator	41.20	11.89	0.06
26. Rehabilitation Coun- selor	31.51	11.52	0.01
27. YMCA Secretary	30.64	13.29	-0.36
28. Recreation Admin- istrator	33.31	12.91	-0.25
29. Social Worker	28.88	12.82	-0.04
30. Social Science Teacher	26.14	10.90	-0.10
31. School Superin- tendent	20.51	10.77	0.10
32. Minister	11.28	13.13	0.01
33. Librarian	25.09	9.93	0.24
34. Artist	22.92	8.63	0.07
35. Music Performer	27.91	8.54	-0.07
36. Music Teacher	23.11	9.98	-0.08
37. CPA Owner	27.65	11.20	0.31
38. Senior CPA	36.35	10.55	0.33
39. Accountant	31.04	10.80	0.02
40. Office Worker	29.62	11.09	-0.02
41. Credit Manager	34.47	13.16	-0.06
42. Chamber of Commerce	36.59	11.68	-0.12
43. Business Education Teacher	32.36	11.08	-0.05

<u>Scale</u>	<u>Mean Std.Score</u>	<u>S.D.</u>	<u>Corr. with ZQPR</u>
44. Purchasing Agent	33.22	8.61	0.01
45. Banker	23.77	8.56	0.11
46. Pharmacist	26.43	7.98	-0.20
47. Mortician	23.88	7.62	-0.31
48. Sales Manager	26.61	10.74	-0.10
49. Real Estate Salesman	32.38	8.14	-0.10
50. Life Insurance Salesman	23.97	9.90	-0.20
51. Advertising Man	25.53	10.17	-0.00
52. Attorney	28.01	8.56	0.13
53. Author-Journalist	27.58	7.70	0.17
54. President Manu- facturing Concern	22.89	8.83	0.06
55. Computer Programmer	43.19	10.81	0.37
56. Interpreter	28.11	10.45	0.21
57. A-B Doctor	43.96	12.98	0.03
58. Academic Achievement	48.54	9.66	0.32
59. Liberal Conservative	43.69	8.29	0.16
60. Masculinity- Femininity	51.74	8.14	-0.01
61. Occupational Level	60.50	7.21	0.15
62. Extroversion- Introversion	45.31	19.29	0.18
63. Specialization Level	42.92	9.14	0.32
64. NROTC Retention	51.76	11.26	-0.15
65. Managerial Effectiveness	52.01	9.29	0.03

APPENDIX C

THE EFFECT OF SELECTION ON VALIDITY

This appendix contains a statistical explanation of the effect of selection of individuals on a validity coefficient. For simplicity, only the bivariate case will be considered here (see Ref. 17).

Suppose that a regulation had been in effect that no one with a baccalaureate QPR (BQPR) below 2.50 would be admitted to the graduate program. Let's denote the BQPR as variable x . Denote the performance criterion score as variable y . If selection is on the basis of variable x , the regression line of y on x will not be affected, and can be assumed to be the same for the curtailed and extended distribution. If the curtailed group is designated by x and y , and the extended group by X and Y , then the assumption can be written as:

$$\dot{y} = r_{xy} \frac{s_y}{s_x} x \quad (1)$$

and

$$\dot{y} = R_{XY} \frac{S_Y}{S_X} X \quad (2)$$

Since it is assumed that the predicted $y(Y)$ for a given $x(X)$ is the same for both cases, the slopes of the two regression lines are equal, and can be written as

$$r_{xy} \frac{s_y}{s_x} = R_{XY} \frac{S_Y}{S_X} . \quad (3)$$

Moreover, not only is the mean of y for given x the same for both groups, but also the dispersion of y 's for given x , hence

$$s_y \sqrt{1 - r_{xy}^2} = S_Y \sqrt{1 - R_{XY}^2} . \quad (4)$$

Consider the case where one knows the variance of x for the curtailed group and the extended group. In order to obtain the equation for R_{XY} , one may solve equation 3 for S_Y , obtaining

$$S_Y = \frac{r_{xy} s_y S_X}{R_{XY} s_x} \quad (5)$$

and then substitute this value for S_Y in equation 4, obtaining

$$s_y \sqrt{1 - r_{xy}^2} = \frac{r_{xy} s_y S_X}{R_{XY} s_x} \sqrt{1 - R_{XY}^2} . \quad (6)$$

Solving explicitly for R_{XY} gives

$$R_{XY} = \frac{1}{1 + \frac{s_x^2}{s_x^2} \left(\frac{1}{r_{xy}^2} - 1 \right)} . \quad (7)$$

APPENDIX D

GRADUATE EDUCATION POTENTIAL CATEGORIES FOR CLASSIFICATION

1. Capable of direct entry into a technical curriculum
2. Capable of direct entry into a non-technical graduate program not requiring mathematical aptitude.
3. Potentially capable of entry into a technical curriculum after a refresher course of 3-6 months duration.
4. Capable of direct entry into a non-technical graduate program requiring some mathematical aptitude (would also meet categories 5).
5. Capable of entry into an updating program which may lead to qualification for a technical curriculum after 6-12 months study.
6. Capable of qualifying for category 5 by taking off-duty courses.
7. No apparent potential for graduate education.
8. No accredited baccalaureate degree. Needs undergraduate program.

GRADUATE EDUCATION POTENTIAL CLASSIFICATION CRITERIA

1. Capable of direct entry into a technical curriculum
 - 1) Possess an accredited baccalaureate degree with a minimum preparation of mathematics through the differential and integral calculus of several variables and a one year course in general physics using calculus as a tool. Marks achieved in all mathematics and physics courses be C or better and the overall average of these grades at least 2.50 on a scale having 2.00 as C.
 - 2) When academic credits include college chemistry or engineering credits taken in the junior or senior year an overall average of 2.50 or better in all math, physics, and upper division engineering may be substituted for the required overall average in math and physics.

2. Capable of direct entry into a non-technical graduate program not requiring mathematical aptitude
 - 1) Possess an accredited baccalaureate degree with an overall average of at least 2.75 on a scale having 2.00 as C.
 - 2) Have an academic major in a non-technical subject with an average of at least 3.00 in that subject. A general liberal arts degree with a 3.00 average may be used as a substitute if no major was pursued.
3. Potentially capable of entry into a technical curriculum after a refresher course of 3-6 months duration
 - 1) Possess an accredited baccalaureate degree.
 - 2) Have passed mathematics courses through the differential and integral calculus of several variables and a one year course in general physics using calculus as a tool. Have at least a 2.00 average in all mathematics and physics courses.
 - 3) When courses of 2) have been taken, a GRE quantitative aptitude score of 550 or higher may be substituted for the 2.00 average.
4. Capable of direct entry into a non-technical graduate program requiring some mathematical aptitude
 - 1) Possess an accredited baccalaureate degree with an overall average of at least 2.50 on a scale having 2.00 as a C average.
 - 2) Have completed successfully (C grades at least) a minimum of two college courses in mathematics at the level of college algebra or higher and have a Graduate Record Examination (GRE) Quantitative Aptitude score of 500 or higher.
 - 3) A GRE Quantitative Aptitude score of 550 or higher may be used in lieu of criteria 2).
5. Entry into an updating program which may lead to Qualification for a technical curriculum after 6-12 months of study
 - 1) Possess an accredited baccalaureate degree.
 - 2) Have completed successfully (at least a C grade) at least one college mathematics course in algebra, trigonometry, or math analysis.

- 3) When no college mathematics has been taken, a baccalaureate degree with an overall average of 2.75, where 2.00 is a C average, or a GRE Quantitative Aptitude score of 550 may be substituted.
6. Could qualify for category 5 by taking off-duty courses
 - 1) Possess an accredited baccalaureate degree.
 - 2) No evidence of mathematical inadequacy in form of low marks in courses attempted.
7. No apparent potential for graduate education
 - 1) Possess an accredited baccalaureate degree.
 - 2) Not qualified in categories 1-5.
 - 3) Evidence of mathematical inadequacy by low marks in courses attempted.
8. No accredited baccalaureate degree

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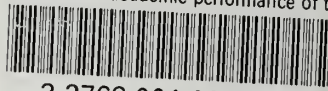
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